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R & D CATALOG FORM

DATE	29 January 1968
1. PROJECT TITLE/CODE NAME	Image Analysis Study
2. SHORT PROJECT DESCRIPTION	The third year follow-on program of research into the concepts of image analysis.
3. CONTRACTOR NAME	
4. LOCATION OF CONTRACTOR	25X1
5. CLASS OF CONTRACTOR	Research Laboratory (Commercial)
6. TYPE OF CONTRACT	CPPF
7. FUNDS	FY 1967 FY 1968 FY 1969
8. REQUISITION NO.	NA
9. BUDGET PROJECT NO.	25X1 NP-A-1-04018
10. EFFECTIVE CONTRACT DATE *(Begin - end)*	March 1968 - February 1969
11. SECURITY CLASS.	A.A. - Secret T. - Unclassified W. - Secret
12. RESPONSIBLE DIRECTORATE/OFFICE/PROJECT OFFICER TELEPHONE EXTENSION	DDI/NPIC/TDS 25X1

13. REQUIREMENT/AUTHORITY Thorough evaluation and exploitation of contemporary and oncoming imagery requires information about the basic processes which is not now available. This study is essential to provide a basis for evaluation, interpretation, and communication in the field of image analysis.

14. TYPE OF WORK TO BE DONE

Applied research and experimentation, including a comprehensive review of available literature, in the nature of photographic and other images.

15. CATEGORIES OF EFFORT

MAJOR CATEGORY	SUB-CATEGORIES
Image Analysis Program	Optical Systems

16. END ITEM OR SERVICES FROM THIS CONTRACT/IMPROVEMENT OVER CURRENT SYSTEM, EQUIPMENT, ETC.

Reports on the basic nature and parameters of photographic and other images, including rigorous descriptions of image forming and recording processes and means of compensating for degradation caused by acquisition, reproduction, transmission, and viewing.

17. SUPPORTING OR RELATED CONTRACTS *(Agency & Other)***/COORDINATION**

Basic coordination was accomplished with DD/S&T/ORD and with offices of DOD during the first phase, community coordination has been maintained on an informal and continual basis through EXRAND, SAFSS and SASPPF and by related briefings.

18. DESCRIPTION OF INTELLIGENCE REQUIREMENT AND DETAILED TECHNICAL DESCRIPTION OF PROJECT *(Continue on additional page if required)* Information from this study will help extract more intelligence from imagery, to deal with the increasing varieties of imagery available and to reduce available information into a form acceptable to computers for calculations and storage. Tasks under this project include studies in optics, photographic processes, the imaging properties of photographic material, systems performance, the physics of partially coherent photometry, and microdensitometers.

19. APPROVED BY AND DATE

OFFICE	DEPUTY DIRECTOR	DDCI

FORM 2229 SECRET GROUP 1 (1-13)

Pages.

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25X1

[redacted]

UNSOLICITED PROPOSAL FOR IMAGE ANALYSIS (U)

TO-B 21-68

GROUP 1
EXCLUDED FROM AUTOMATIC
DOWNGRADING AND DECLASSIFICATION

21 December 1967

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PROPOSAL FOR CONTINUATION OF IMAGE ANALYSIS (U)

INTRODUCTION

[redacted] are pleased to 25X1
submit this unsolicited proposal for the continuation of [redacted] 25X1
Task Order 22. The technical details are not included in this proposal since they are contained in the Second Quarterly and the Interim Reports on the present contract. Therefore, only a Work Statement and Cost Proposal are included in this document. For further discussions concerning the items in the Work Statement, the reader is referred to the above mentioned reports.

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REVISED WORK STATEMENT
FOR
IMAGE ANALYSIS (U)

[redacted] will provide the necessary services and personnel to perform the following work. 25X1

PHASE I COHERENCE MEASUREMENTS

1. Experimentally vary the spatial coherence of suitable exploitation instruments and determine the effect of various coherence intervals on imagery having object sizes of interest to the sponsor.

   a. Perform mensuration experiments with coherence interval as a variable parameter

      1. Use imagery containing detail sizes of interest to the sponsor.

   b. From the mensuration experiments correlate coherence interval in the object plane with object size expressed in number of resolution elements

   c. Determine the usable working range of the instruments where coherence effects are absent in mensuration studies.

2. Develop an approach to evaluate lens systems consistent with item 1.

   a. Ideal targets

   b. Grain limited film targets

3. Consider a system resolving both image and grain on the same film.

   a. Investigate coherence effects in such a system.

      1. Coherence effects from grain but not from image
      2. Effects of grain coherence effects upon mensuration
      3. From these results determine the working range of the lens system where such coherence effects are not important.

PHASE II SHADED APERTURE INVESTIGATION

1. Determine the practicality of using shaded apertures in instruments viewing grain limited imagery assuming a knowledge of the degree of coherence in the object plane.
   a. Microscope
   b. Viewers
   c. Enlargers
2. Determine and demonstrate that class of problems in which the methods of item (1) are useful.
3. Construction of Optimum Least Squares Filter for the I.D.T.
   a. Construct filters assuming that the correlation between the signal and noise is negligible
      1. Conduct experimental study
      2. From these results construct the filter and demonstrate its use.
   b. Construct filters assuming that the correlation between signal and noise is significant
      1. Evaluate and measure the correlation between the signal and noise
      2. Conduct experimental study
      3. From these results construct the filter and demonstrate its use.
   c. Compare items 3-a.2 and 3-b.3. Demonstrate the improvement obtained using such shaded apertures in a scanning instrument such as the I.D.T.
   d. Determine which classes of objects and for which types of exploitation tasks such Wiener Filters are most useful.

PHASE III I.D.T. EXPERIMENTATION

1. Two-Dimensional Brightness Distribution from Objects Imaged Near Resolution Limit of Recording System

   a. Consider distortions due to brightness distribution when two or more objects of the size of a few resolution elements are imaged close together.

2. I.D.T. Traces

   a. Make carefully controlled IDT traces of aerial photography having known object sizes

      1. Analyze and interpret such traces
      2. Determine accuracy of sizing objects near the resolution limit for such measurements

   b. Use Phase II, item (3) and previous results to improve ability to interpret IDT traces of low-contrast imagery.

3. I.Q. and High Magnification Viewer-Printer

   a. Prepare I.Q. for delivery during contract
   b. Compare the conventional quantizing mode with the differentiating mode in the I.Q. for the recovery of grain limited imagery
   c. Quantitatively and Qualitatively compare the IDT and I.Q.

      1. Scale the shaded apertures for the IDT to fit the I.Q.

         a. Compare the results of using shaded apertures in the I.Q. with the IDT.

      2. Coherence effects
      3. Comparison as photo-interpretative instruments
      4. IDT and I.Q. operating mode

         a. Define that class of imagery where the IDT and the I.Q. are most useful
         b. From the results of the shaded aperture experiments define the optimal operating mode of the IDT and I.Q. for that class of imagery defined in item a above.
         c. Prepare a revised operating manual based on items a and b above.

PHASE IV SUPPORT TASKS

1. Provide support of any special tasks which are requested by the Sponsor for which the technical ability of [redacted] is needed. 25X1
   These tasks especially include

   a. Photo-Chemistry

   b. Electron Microscopy.

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IMAGE ANALYSIS RESEARCH PROGRAM

TECHNICAL AND FISCAL PROPOSAL

October 1967

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I. INTRODUCTION

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I. INTRODUCTION

The goal of the image analysis program can be stated as the development of methods to assist the photo interpreter in obtaining more accurate and reliable information from photographic imagery by the application of objective analysis techniques. Due to the importance of measurement of small-scale objects in the information extraction process, emphasis has been placed on the use of state-of-the-art analysis techniques in making the measurement process more reliable and accurate. Several new developments have recently become available which hold promise of increasing the accuracy of such small scale measurements. One of these is the greater range and control of the film duplication process through the use of low gamma chemistry and improved emulsions. Another is the now practical possibility of digital computer processing of reasonable amounts of imagery, with the resultant advantages of completely arbitrary transformations and spatial filtering techniques. These techniques will be examined to determine how effective they are in aiding the small-scale measurement problem.

The proposed program is divided into three task areas. These are (1) Mensuration Capability of Image Processing Techniques, (2) Film Response Model, and (3) Technical Management and Planning.

II TASK 1

MENSURATION CAPABILITY OF IMAGE PROCESSING TECHNIQUES

II TASK 1 - MENSURATION CAPABILITY OF IMAGE PROCESSING TECHNIQUES

A. Introduction

The goal of this task area is the investigation of current techniques in image processing, and in particular, the application of these techniques to the mensuration problem.

B. Technical Discussion

New equipment and techniques have made the digital approach to image processing feasible, whereas, a few years ago it was technically impossible. In particular, the development of accurate raster scan capability in microdensitometers, high speed magnetic tape recording devices, and much faster computers are the most important developments.

This task area is proposed to study the application of current image processing techniques to the mensuration problem. An image processing system for handling imagery of a resolution well beyond the limit of current operational systems now exists at [redacted] This task area is proposed to study the use of this system in reducing mensuration error, therefore, it is expected that the full resources of this task area on the image analysis program can be devoted to the application of the system to this problem, rather than system development. 25X1

The basic image processing systems consists of several elements. These are recording, processing, and output display. It will be useful to examine the basic elements of the present system, and in particular, point out the areas in which investigations will be made to improve the dimensional fidelity of small scale imagery.

The recording device is a Mann-Data microanalyzer which operates in conjunction with a high speed magnetic tape digitizer, with analog to digital conversion. Raster scan mode is used, with positional accuracy of ± 1/4 micron. Aperture sizes are available down to less than one micron in diameter.

It is possible to perform almost any operation upon the data once it is in digital form by the use of a high speed digital computer. The system presently uses an IBM 360 Model 40 for the computations, with several operations available. The digital data is put in matrix form by the computer for ease of manipulation. The operations that can be presently performed are unit conversion by table reference, Fourier transformation by the Cooley-Tukey algorithm, spatial filtering by any arbitrary two dimensional function, and inverse Fourier transformation.

The output is accomplished by utilizing a half tone technique with a special printer, which has a grey scale of twenty four steps available. The computer software routines required to accomplish the output are available and have been tested and utilized in the mapping of potential lunar landing sites.

The proposed program for this task area involves three phases. These are:

1. <u>Data Collection</u>

Photography made under controlled conditions will be scanned and converted to digital form. It is proposed to use the [redacted] 25X1 mensuration target for this purpose, since both the size and reflectance levels of all target objects have been carefully determined in previous programs. The resolution level will be between 40 and 150 lines/mm, to cover the range of operational material. Several selected samples will be recorded, and used as the reference material in the remainder of the study.

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2. Investigation of Non-Linear Operators

The use of non-linear operators in the unit transformation will be investigated. This ability to use arbitrary operators is of course the great advantage of digital image processing, since it cannot be accomplished in any other manner. Three sets of mensuration data will be compared in this experiment. One set will be the measurements made on the target imagery with conventional comparator measurements. The second will be the measurements obtained using the conventional sensitometric curve as the unit conversion function. This is simply using the effective exposure concept as conversion from density to exposure values. The third set will utilize the mathematical model developed from the film response study as a method of obtaining the input-output relationships between incident exposure and resultant density. If the work done on the effective exposure study is valid, this last method should provide the most accurate answers. The actual model used will not necessarily be exact, but will involve the addition of a second order non-linear term to the conventional effective exposure model. The addition of this term will probably be adequate to handle the most significant non-linear effects. Previous work has shown that large percentage of the non-linearity can be accounted for by the addition of second order functions to the model.

The measurement of the processed images is relatively simple because of the large scale factors involved from input to putput. The real question is the minimization or reduction of the errors due to the photographic process that can be accomplished by image processing.

3. Application of Linear Filters to the Mensuration Problem

This phase of the program will study the usefulness of Weiner filtering to minimize the effects of the grain noise of the film and the image degradation caused by the taking system in the mensuration error problem. The Weiner filter is based on the concept of developing a filter that yields the minimum mean square error over the total signal of interest. Detailed measurement of the photographic noise environment has been performed for conventional operational materials, and this data is available for direct use, without a separate experimental program. Routine procedures and computer software for determining the transfer function of photographic system are available, and can be applied to desired situations with a minimum of effort.

The last year has seen development of the fast Fourier transform (Cooley-Tukey algorithm) technique, which allows frequency plane treatment of digital data at a rate related to the logarithm of the array length rather than a rate proportional to the square of the array size. This has made two-dimensional frequency plane operations economically feasible in terms of computational time. The fast Fourier transform procedure has been implemented as part of the over-all image processing system.

One thing is certain in regard to the use of inverse filtering techniques, and that is the increase in sharpness of edges that is produced Since photographic measurements of interest are generally made from one edge to another of the object being measured, the region of uncertainity about the selection of the point on the edge from which the measurement is made will be greatly reduced. Another way of saying this is that there will be little doubt about the selection of the starting and stopping points when the measurement is performed on the processed image. This increased sharpness has been shown by some preliminary work done with the lunar orbiter photography. However, the real question of interest in this program is whether the sharpened edges appear at the correct location, and if not, how much is the error reduced by image processing as compared with conventional measurement techniques? This program should provide the answers to these questions.

In summary, it is apparent that a sizeable technology now exists for image processing. The main requirement at this time is that of experimental investigation to determine the potential benefits to be derived from using it as an operational tool in increasing the amount and reliability of the information extracted from the available imagery.

III TASK 2

FILM RESPONSE MODEL

III. TASK 2 - FILM RESPONSE MODEL

A. Introduction

The objective of this task area is to develop an operational model of film response characteristics which takes the important non-linearities into account.

B. Technical Discussion

Before discussion of the approach to this problem, it will be useful to examine the application of such a film model. Obviously, the photointerpreter cannot use the model directly in his work. However, what is being considered here is basically developing a description of the input-output relationships in photographic systems, that is, relating the resultant density distributions on a piece of film to the luminance variations of the original scene.

To the system engineer, such a model would certainly be useful, since he is evaluating how well a photographic system records the information presented to it. In the past, the effective exposure concept has been used, but has been shown to be erroneous. With the improvement in both systems and measurement techniques, further progress is suffering from the restrictions of this strictly linear approach. Also, any analysis technique for handling real problems must eventually relate back to the input distribution in terms of exposure. Therefore, any analysis technique which is to prove useful must eventually attack this problem of the non-linearity of the photographic process.

Previous work has definitely established that the effective exposure concept as originally hypothesized is in error, as shown by the harmonic distortion terms generated. During the past year, work has been done in establishing limits on this problem, and developing a better quantitative measure of the actual errors that are present when effective exposure is used.

The approach to be taken in this program is to assume that effective exposure is a non-linear function of input exposure, where the non-linear function can be represented as a linear convolution plus a quadratic convolution. These two operators will have the same form as the first two terms of a Volteria-Wiener functional series expansion.

Functional series are very general methods for the representation of non-linear systems. However, in the present state of these methods, practical limitations exist, in that if the non-linearities in a system are too violent, the number of terms required for a good approximation becomes very large. Previous work has shown that this is not the case with photographic systems, since they are essentially band limited types of systems. This is the reason for choosing only a quadratic term in addition to the conventional linear convolution. It is quite probable that the addition of this term will provide a model adequate enough for all current problems of interest.

The actual program to be executed will have as its goal the determination of the second order kernal of the series expansion for 3404 original material. Current mathematical methods are such that the remaining step in the problem is experimentation to determine this function. The end result will be an explicit input-output relationship, which can be implemented and tested.

The derived model will be implemented and tested using controlled photography, and of the reduction in error by using this technique as compared to the linear approach will be determined. The end result of this program will be an operational tool which can be utilized in system analysis and other situations in which it is required to obtain an accurate description of the input stimulus which produced an image.

IV TASK 3

TECHNICAL MANAGEMENT AND PLANNING

IV. TASK 3 - TECHNICAL MANAGEMENT AND PLANNING

A certain number of hours must be devoted to technical management and planning. This will include technical coordination, technical meetings, and reviews, and compliance with major reporting requirements.

[redacted] 25X1

Work Statement

[redacted] will provide the necessary facilities and personnel to perform the following tasks: 25X1

Task No. 1

Investigation of methods of automatic correction of Mensuration errors produced by photographic effects. The usefulness of the following will be evaluated:

(a) Nonlinear operators
(b) Linear filters
(c) Wiener filters to minimize noise.

Data will be collected with the microdensitometer using previously generated test photography as sample material.

Task No. 2

Investigation of second order functionals to account for the important nonlinear effects in photographic film. This study will utilize existing mathematical approaches, and will assess the applicability of such to the photographic situation. All efforts will be directed toward the development of a pragmatic solution to this problem.

Task No. 3

[redacted] will provide support to the total program as required by [redacted] 25X1 25X1

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